Chapter Four

Bridge Load Rating

4.1 INTRODUCTION

The National Bridge Inspection Standards (NBIS) requires each highway department to inspect, prepare reports, and determine load ratings for structures defined as bridges located on all public roads. The NBIS is contained in 23 CFR 650, Subpart C. In Delaware, bridges are defined as having an opening of greater than 20 sq ft [1.86 m^2]. The federal definition of a bridge is "a structure including supports erected over a depression or an obstruction, such as water, highway, or railway, and having a track or passageway for carrying traffic or other moving loads, and having an opening measured along the center of the roadway of more than 20 feet between undercopings of abutments or spring lines of arches, or extreme ends of openings for multiple boxes; it may also include multiple pipes, where the clear distance between openings is less than half of the smaller contiguous opening". Only bridges that meet the federal definition are included in the National Bridge Inventory.

For structural types, materials, and analysis methods not dealt with in this manual, contact the Bridge Management Section.

4.1.1 RESPONSIBILITY

Most bridges in Delaware are state owned and operated. In Delaware, bridges that are not owned and operated by the state are usually owned by cities (Wilmington, Elsmere, and Milford), railroads (CSX, Norfolk Southern), Delaware River and Bay Authority (DRBA), the Department of Natural Resources and Environmental Control (DNREC), or the Army Corps of Engineers. Inspection and rating of these bridges meeting federal requirements are the responsibility of the owner and must be conducted in accordance with the NBIS. Owners forward their bridge inspection and rating results to the Bridge Management Section, which then consolidates the results and forwards them to FHWA for inclusion in the National Bridge Inventory (NBI).

4.1.2 ASSUMPTIONS

Engineers must make assumptions in order to efficiently analyze existing bridges. This is due to the wide variety of structural materials available (e.g., steel, concrete, wrought iron, timber, masonry and/or combination thereof), assortment of structural types, and variations in quality and strength of the materials. These assumptions consider the policies and procedures with which the structures were designed, the recommendations in AASHTO's *Manual for Condition Evaluation of Bridges*, and policies of the DelDOT Bridge Design Section included in this chapter. For new structures, standard design criteria shall be used. During

rehabilitation, material testing is usually performed and these values shall be used.

4.1.3 LOAD RATING LEVELS

Load rating analysis of bridges is performed to determine the live load that structures can safely carry. Bridges are rated at three different stress levels, referred to as Inventory Rating, Operating Rating, and Posting Rating.

Inventory rating is the capacity rating for the vehicle type used in the rating that will result in a load level which can safely utilize an existing structure for an indefinite period of time. Inventory load level approximates the design load level for normal service conditions.

Operating rating will result in the absolute maximum permissible load level to which the structure may be subjected for the vehicle type used in the rating. This rating determines the capacity of the bridge for occasional use. Allowing unlimited numbers of vehicles to subject the bridge to the operating level will compromise the bridge life. This value is typically used when evaluating overweight permit vehicle moves.

The posting rating is the capacity rating for the vehicle type used in the rating that will result in a load level which may safely utilize an existing structure on a routine basis for a limited period of time. The posting rating for a bridge is based on inventory level plus a fraction of the difference between inventory and operating. Posting level and fraction is determined using the criteria shown in Figure 4-2.

Structural capacities and loadings are used to analyze the critical members to determine the appropriate load rating. This may lead to load restrictions of the bridge or identification of components that require rehabilitation or other modification to avoid posting of the bridge.

4.1.4 LOAD RESTRICTION POSTING

When a bridge is not able to safely carry the loads allowed by State Statute, it is posted for its reduced capacity. The Bridge Management Section implements load restrictions by preparing a "Load Restriction Resolution," which is signed by the Chief Engineer. The Bridge Management Section then distributes letters to the proper authorities, including local fire companies, school transportation directors, the Delaware Authority for Regional Transport (DART), Senators, and Representatives. Upon completion of replacement or rehabilitation of a posted structure, the Bridge Management Section prepares a "Removal of Load Restriction Resolution," signed by the Chief Engineer and distributed as above.

It is the Department's policy to restrict loads on bridges when the posting-rating factor drops below one for any of the Delaware legal truckloads. See Figures 4-2 and 4-3. The minimum posting is 3 tons [2.7 metric tons]. For further information on posting, contact the Bridge Management Engineer.

Figure 4-1a
Sample Load Rating Plan Sheet Note (Bridges Required To Be Rated)

LOAD RATINGS

AASHTO HS20-44 (MS 18) TRUCK (36 TONS)
OPERATING RATING:
CONTROL POINT - SPAN 1 @ 5.00 TENTH (ULTIMATE MOMENT CAPACITY)
POSITIVE ACTION RATING FACTOR = 2.55
LOAD RATING = 91.9 TONS
INVENTORY RATING:
CONTROL POINT - SPAN 1 @ 5.00 TENTH (ULTIMATE MOMENT CAPACITY)
POSITIVE ACTION RATING FACTOR = 1.53
LOAD RATING = 55.0 TONS

DELAWARE 4 AXLE SINGLE UNIT S437 TRUCK (37 TONS)
OPERATING RATING:
CONTROL POINT - SPAN 1 @ 5.00 TENTH (ULTIMATE MOMENT CAPICITY)
POSITIVE ACTION RATING FACTOR = 2.08
LOAD RATING = 76.9 TONS
INVENTORY RATING:
CONTROL POINT - SPAN 1 @ 5.00 TENTH (ULTIMATE MOMENT CAPACITY)
POSITIVE ACTION RATING FACTOR = 1.24
LOAD RATING = 46.0 TONS

Figure 4-1b
Sample Load Rating Plan Sheet Note (Bridges Not Required To Be Rated)

LOAD RATINGS

THIS PROJECT DOES NOT CHANGE THE LOAD RATING OF THE BRIDGE.

A CURRENT LOAD RATING OF THE BRIDGE IS ON FILE AND MAY BE OBTAINED FROM THE BRIDGE MANAGEMENT SECTION.

Figure 4-2
Safe Load Posting Decision Flow Chart

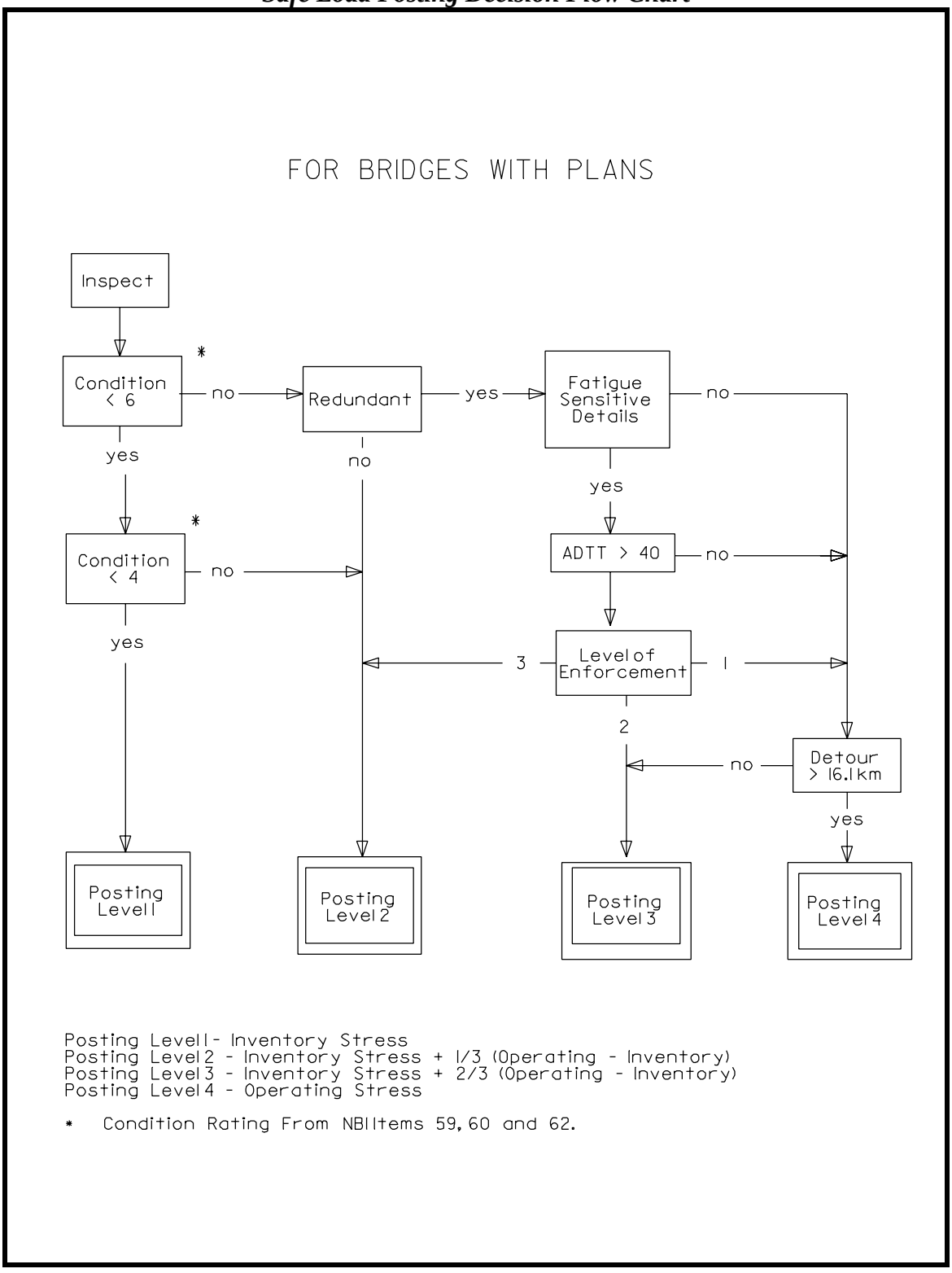

Figure 4-3
Enforcement Levels

Level of Enforcement	Degree of Enforcement of Load Limit
1	Vigorous enforcement of weight limit (Interstate, US13 and US113)
2	Moderate enforcement of weight limit (Delaware and US Routes except for those in Level 1)
3	Minimal enforcement of weight limit (usually local roads)

4.2 BRIDGE INSPECTIONS

Prior to rating an existing bridge, the engineer must perform or review results of a recent detailed inspection. The engineer rating the bridge also needs a complete description of the bridge, as-built plans, any modifications since it was built, and its present condition. In lieu of plans, a detailed set of measurements and/or sketches from actual field measurements will be needed.

By law, all bridges on the National Bridge Inventory are required to be inspected at least every two years. Inspection of bridges is done in conformance with AASHTO's *Manual for Condition Evaluation of Bridges*, FHWA's *Recording and Coding Guide for Structure Inventory and Appraisal of the Nation's Bridges*, DelDOT's *Bridge Management Manual*, and DelDOT's *Element Data Collection Manual*. Some structures require more detailed and different types of inspections to determine their actual condition and capacity. Bridges in poor structural condition require more frequent inspections. Bridges are not typically rated as a part of their routine biennial inspections. However, they may be rated as part of any and all inspections at the discretion of the Bridge Management Engineer. Load rating of bridges during inspections is usually prompted by discovery of obvious loss of section, continuing deterioration, and suspected loss of capacity.

When conditions warrant, reduced sections or reduced allowable stresses should be used to obtain a load rating that indicates the actual condition and capacity of the structure. Areas of deterioration would be given special attention during field inspection, since a primary member that is reduced in section may control the capacity of the structure.

4.2.1 INSPECTION TYPES

The following inspection types are included in the NBI Standards: routine; underwater; fracture critical; and special. Routine inspections are regularly scheduled inspections consisting of observations and/or measurements needed to determine the physical and functional condition of the bridge, to identify any changes from initial or previously recorded conditions, and to ensure that the structure continues to satisfy present service requirements. An underwater inspection is an inspection of the underwater portion of a bridge substructure and the surrounding channel

which cannot be done visually at low water by wading or probing, generally requiring diving or other appropriate techniques. A fracture critical inspection involves a hands-on inspection of a fracture critical member or member components that may include visual or other nondestructive evaluation. A special inspection is an inspection scheduled at the discretion of the bridge owner, used to monitor a particular known or suspected deficiency. A special inspection can be scheduled with the Bridge Management Section if the structural deficiencies are not documented in sufficient detail in previous reports. All inspection reports are filed and available for review in the Bridge Management Section.

4.2.2 INSPECTION FILES

After field inspection, the Bridge Management Section enters the inspection results into a Pontis database. The Bridge Management Section maintains a file of inspection results for each bridge, along with maintenance records, contract plans, etc. This information indicates the current condition of the bridge, which can then be used in load rating calculations of the structural elements.

4.3 BRIDGE REPLACEMENT AND REHABILITATION RATING

It is the Department's policy to design new bridges and to rehabilitate existing ones for AASHTO live load requirements. This section will discuss the ratings required for new and rehabilitated bridges.

4.3.1 REQUIRED RATINGS

Department policy is to design all new and rehabilitated bridges on state-maintained roads, for an inventory load rating factor of 1.0 or greater for all Delaware legal loads as given in Figure 4-2. In addition, bridges must be designed to fulfill AASHTO design load requirements for LRFD. (Refer to design requirements in this manual.) If a bridge is not designed for the Delaware legal load, the Project Manager shall submit a Design Exception for approval. Design Exceptions are prepared according to Chapter 2, outlining the justification for deviation from the standard. Design Exceptions are recommended by the Project Manager and forwarded through Department Channels for approval by the Chief Engineer. On some rehabilitation projects, such as historical or temporary bridges, however, the scope of work may be limited, making it impractical to provide this minimum rating for the bridge. In this case the bridge shall be designed for an inventory rating as close to 1.0 as possible for the controlling load.

4.3.2 RATED STRUCTURES AND ELEMENTS

All bridge replacement and most bridge rehabilitation projects shall be rated. DelDOT policy is to rate only the bridge superstructure. The need for rating replacement or new structures is to determine the actual load capacity. Load rating of rehabilitated structures is required when:

- The bridge has not been previously rated (check with the Bridge Management Section to verify that a current rating of the superstructure using BRASS is on file).
- Testing provides actual material strength.
- Modifications are made that change dead loads on the structure.

- Inspection reveals section loss of members.
- Structural members are replaced or repaired (excluding painting).

When in doubt about the need to do a load rating, check with the Bridge Design and Bridge Management Engineers.

4.4 LOAD RATING METHODS

Load rating methods include analysis and, in some cases, load testing. The Department has a preferred method of load rating and computer software that should be used to perform the analysis. For some types of bridges, other methods of load rating may be required. Load testing may be used under certain circumstances with appropriate methods and procedures.

4.4.1 ANALYSIS METHODS

Analysis methods recognized by the Department include the Load Factor Method, Working Stress Design Method, and Load and Resistance Factor Method. These methods vary based on placing the factor of safety on the loads, structural resistance, or a combination of both.

4.4.1.1 Load Factor Method

The required method of load rating in Delaware is the load factor design (LFD) (ultimate strength) method except as noted in Section 4.2.1.2. Ratings are determined by calculating the ratio of the yield strength of the member to the factored loads, as outlined in Chapter 6 of AASHTO's *Manual for Condition Evaluation of Bridges*.

4.4.1.2 Working Stress Design Method

If rating by the LFD method is not possible, the working (allowable) stress (ASD) method should be used. The working stress method should be used to load rate timber bridges. Other types of bridges may be rated by the working stress design method if approved by the Bridge Management Engineer.

4.4.1.3 Load and Resistance Factor Method

Load and resistance rating methods are under development and not used at this time.

4.4.2 TOOLS

Ratings shall be done using the current version of Wyoming Department of Transportation's BRASS Girder computer program. Note that BRASS data input is in U.S. customary units.

Ratings for timber bridges shall be done by the working stress method using BRASS Girder.

When BRASS cannot be used due to geometry, structure type, or material, other computer programs such as STAAD and other advanced techniques such as finite element analysis, AASHTO-ware products, or hand calculations may be used with approval of the Bridge Management Engineer.

4.4.2.1 BRASS Data Set

Rating input data for each bridge are stored in a BRASS ASCII data file. This data file is developed in a command format. Each line begins with a command which

describes data entries referred to as parameters. A sample BRASS data set is shown in Figure 4-4. The BRASS data set is the input for running the BRASS program and calculating the load rating of the bridge. Data sets are prepared for each span of a bridge. An exception is simple span bridges consisting of multiple identical spans where only the worst-case span needs to be analyzed. On continuous spans, all spans should be analyzed due to the influence loads each span has on the others. When complete, the data set shall be forwarded to the Bridge Management Section for use in:

- updating the National Bridge Inventory and
- modifying the overweight vehicle permit routing system.

4.4.2.2 Data Set Standards

Title (TLE) cards shall be the first cards in the data set. Title cards shall contain standard information including bridge number, span number, road carried, road or feature crossed, total number of spans, bridge type, contract number built or rehabilitated under, the year built, and the name of the rater.

Comment cards must be included in the data set and include any and all assumptions made by the Engineer, such as dead load and live load distribution.

File names shall consist of:

For single span: C-NUM.DAT
For multiple span: C-NUM_#.DAT

where:

C = County Code (1,2, or 3 for New Castle, Kent and Sussex Counties, respectively)

NUM = Three-digit bridge number (add a fourth digit suffix to bridge number if required)

= Span number or description of element rated

Examples: 1-001.dat
1-001A.dat
1-001_s1.dat

Do not use spaces or special characters in the data file name.

4.4.3 LOAD TESTING

Load rating by load testing may be feasible in special cases such as the following:

- When analytical results provide a posting or operating rating factor less than one, but the bridge is otherwise showing no visual signs of distress.
- When record construction plans for the bridge are not available.
- Special types of bridges that cannot be analytically rated.
- When calibrating BRASS data including distribution, fixity, or composite action.

The Department performs load testing by driving a truck of known axle weights over a bridge. Stresses are then measured in the load-carrying members with strain gauges and specially designed data analysis equipment. These axle weights and actual measured stresses are used to calibrate the BRASS input data. A more realistic rating of the bridge can then be obtained for all Delaware legal loads.

Figure 4-4
Typical BRASS Load Rating Data Set

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TLE BRIDGE 1-218, N.C. 302 OVER WHITE CLAY CREEK, BUILT 1991
TLE 2 SPAN STEEL CONTINUOUS, COMPOSITE, CONTRACT 84-071-03,INTERIOR STRINGER
ANL 1,0,4
XST 1,WN36X135
XSA 1,50
XSC 102.0,8.5,2.0,0.0,0.0,0.0
XST 2,WN36X135
XSA 2,50
XSG 6,12,5,3.94
XSG 7,12,5,7.06
SPA 1,60.0,5
SPC 1,45.0,1,2
SPD 60.0,2
FIX 0,1,0,1,1,0
SPA 2,60.0,5
SPC 2,15.0,2,1
SPD 60.0,1
FIX 1,1,0,0,1,0
PS1  , ,4.5,50
PS2 8,,60
COM N.C.D.L. = 939 (DECK) + 25 (HAUNCH) + 118 (SIP FORM + CONC IN SIP)
COM C.D.L. = 298 (PARAPETS)
DLD 1,1.082,0.298
LDE 1,1, ,DIAPHRAGMS, UTILITY HANGERS, SPLICE PLATES
PTD 0.0,0.12,1,14.0
PTD 0.0,0.18,1,20.0
PTD 0.0,0.18,1,24.0
PTD 0.0,0.12,1,34.0
PTD 0.0,0.18,1,40.0
PTD 0.0,0.18,1,44.0
PTD 0.0,0.285,1,45.0
PTD 0.0,0.12,1,54.0
PTD 0.0,0.12,2,14.0
PTD 0.0,0.18,2,20.0
PTD 0.0,0.18,2,24.0
PTD 0.0,0.12,2,34.0
PTD 0.0,0.18,2,40.0
PTD 0.0,0.18,2,44.0
PTD 0.0,0.12,2,54.0
LLD 3, 1.605,,,,,
TR1 HS20T,S220,S335,S437,T330,T435
TR2 T540
DES 3, 1
INV 1.3, 1.0, 1.67, 1.0, 1.0, 1.0
OPG 1.0, 1.0, 1.67, 1.0, 1.0, 1.0
PST 1.3, 1.0, 1.00, 1.0, 1.0, 1.0
SLD 1.0, 1.0, 1.0, 1.0, 1.0, 1.0
SL1 104,4
SL2 0,15
SL1 105,4
SL2 0,15
SL1 200,5
SL2 0,15
SL4 50, ,1,0.5,7.5
```

Figure 4-5a
Axle Loadings and Spacings

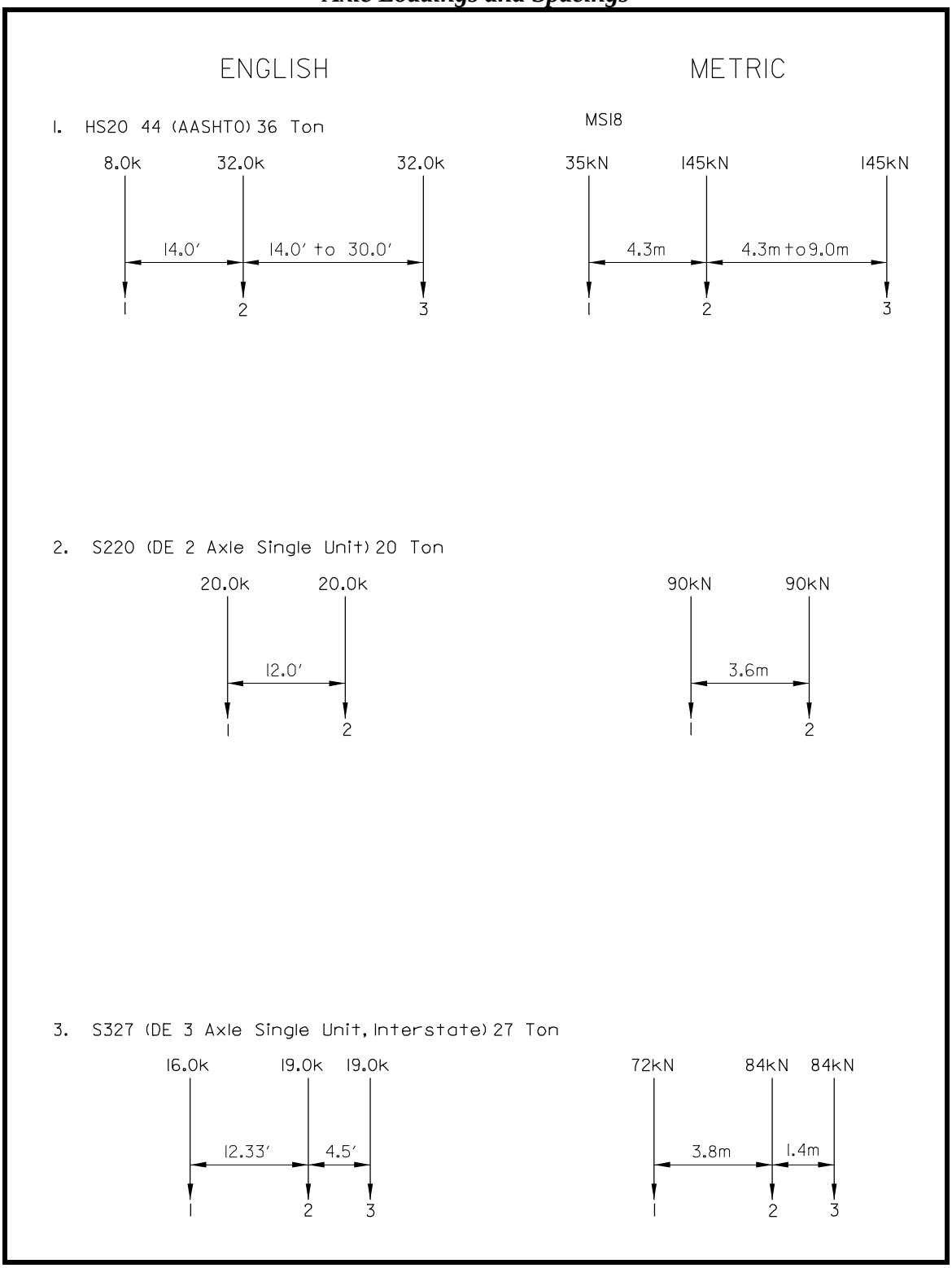


Figure 4-5b
Axle Loadings and Spacings

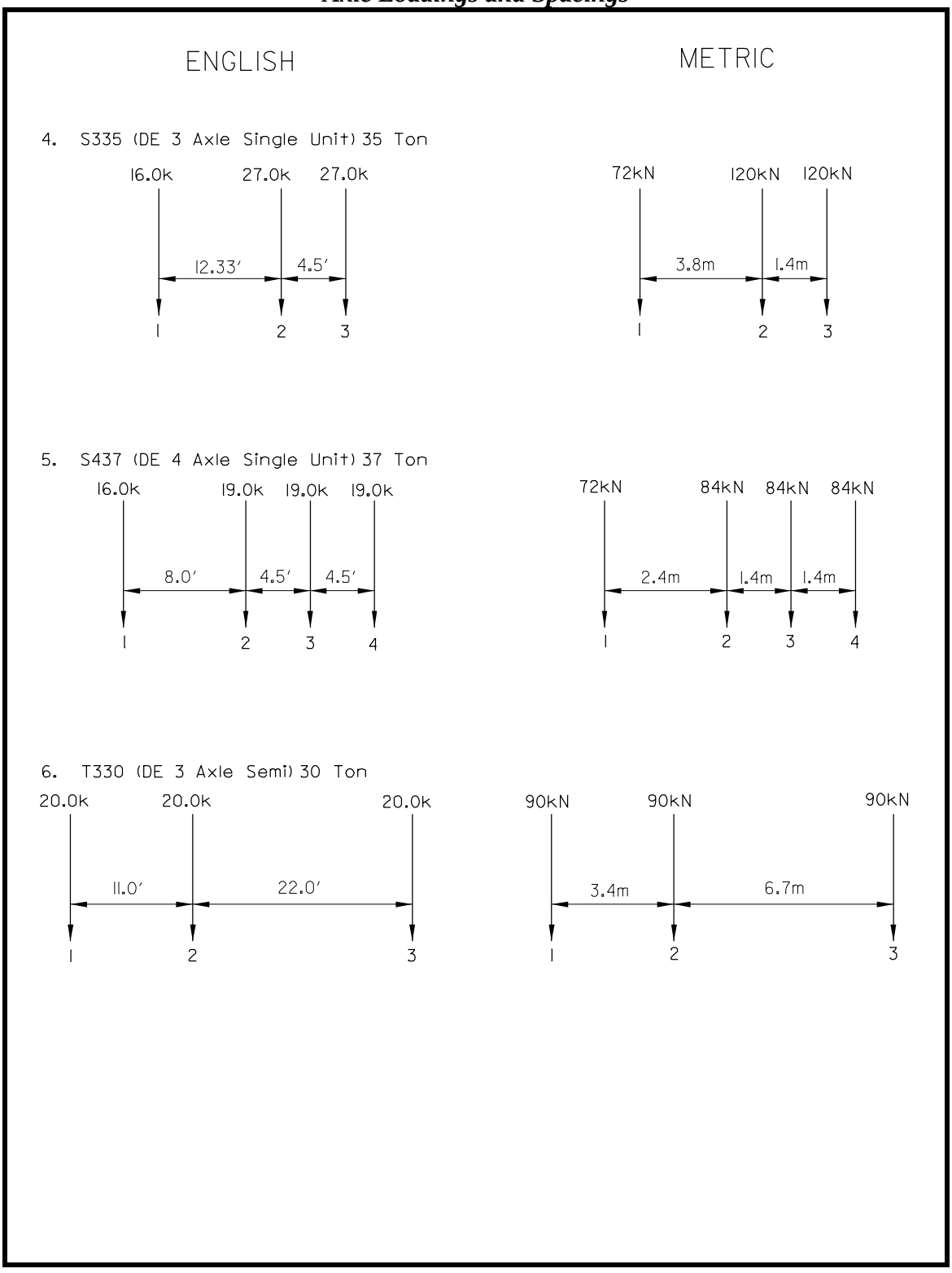
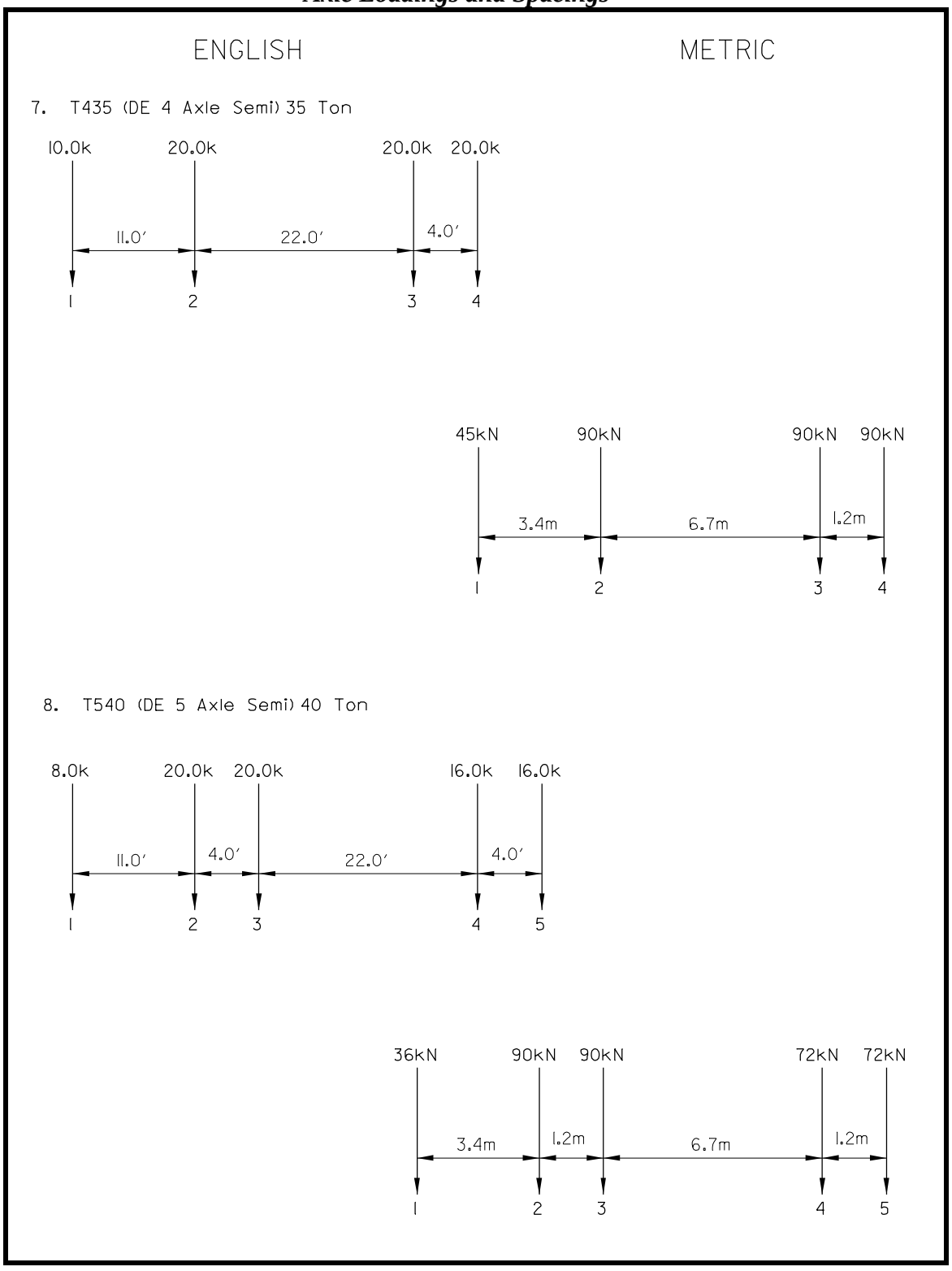


Figure 4-5c
Axle Loadings and Spacings



4.5 ANALYTICAL STEPS IN LOAD RATING

Analytical steps in load rating are detailed procedures that an engineer goes through in performing a load rating analysis.

The analytical steps required to rate any member are independent of the role played by the member in the overall structure. The method of analysis within any of the steps will vary for each member, depending on the member and the choice of load factor or working stress method, but the function of the calculations will be the same. The following analytical steps are required:

1. Determine section properties.
2. Determine allowable and/or yield stresses.
3. Calculate section capacities.
4. Determine dead load effects.
5. Calculate dead load portion for section capacity.
6. Calculate live load effect.
7. Calculate live load impact and distribution.
8. Calculate allowable live load factor.

The stress levels used to analyze critical members and determine the appropriate inventory and operating rating are outlined in AASHTO's *Manual for Condition Evaluation of Bridges*.

4.5.1 RATED MEMBERS

It is Department policy to rate only the primary load-carrying members in a bridge. This is normally the slabs, girders, trusses, or arch ring. Concrete box culverts are rated as rigid frames.

Not included in the load rating are the deck slab, piers, abutments, and foundations. The condition of these elements shall be considered, and they shall be assumed to safely carry the loads transmitted to them unless there is evidence of serious deterioration.

4.5.2 PLAN SHEET RATING NOTES

When ratings are performed in conjunction with the preparation of design drawings, the analysis results are included in the project notes on the plans. It is not necessary to place the results of every Delaware legal load truck on the plans unless a rehabilitated bridge is not designed for the full Delaware legal load and requires posting. Department policy is to place load rating results on the plans for the HS20-44 and controlling truck only. Figure 4-1a is the format used for recording the bridge load rating on design plans.

Bridge maintenance and rehabilitation contracts that do not affect the load-carrying capacity of the structure shall include the optional plan sheet note given in Figure 4-1b.

4.6 LIVE LOADS

Bridge capacity depends upon bridge geometry, material strength, condition, structure type, etc. As related to trucks, a bridge's capacity depends not only upon the gross weight, but also upon the number and spacing of the axles and the distribution of load between the axles. Since it is not practical to rate a bridge for the countless axle configurations, Delaware's highway bridges are rated for six standard vehicles which are representative of actual vehicles on the highways. DelDOT's standard rating trucks are HS20-44, S220, S327, S335,

S437, T330, T435, and T540. (See Figure 4-5.) Bridges are also rated for the AASHTO HS20 truck and lane load. Non-DelDOT owned highway bridges are rated in the same way.

4.6.1 LOAD DISTRIBUTION

Live load distribution shall be as per AASHTO's *Guide Specification for Distribution of Load or Standard Specifications for Highway Bridges*.

In some cases load distribution may be modified based on the results of load testing. See Section 4.2.3.

4.7 LOAD RATING EXAMPLE

Illustrative load rating examples are given in AASHTO's *Manual for Condition Evaluation of Bridges* and in BRASS. The Manual illustrates hand methods of analysis using allowable stress and load factor methods. BRASS gives computer versions of the same. A BRASS data set is shown in Figure 4-4.

4.8 LOAD RATING REPORT

When ratings are performed in conjunction with the preparation of a replacement or rehabilitation project that alters the load ratings of a bridge, a Load Rating Report shall be submitted to the Bridge Management Engineer. The Load Rating Report shall include the following:

- material properties (assumed and/or measured);
- loading assumptions;
- plans or sketches showing all properties and assumptions;
- printout of BRASS data file(s) (where appropriate);
- documentation of structural model used in analysis, if other than BRASS (where appropriate);
- Inventory, Operating, and Posting summary for HS20 and all legal loads;
- electronic copies of data file(s).

The Load Rating Report shall be submitted as soon as possible after Final Construction Plans are complete.